Design and Simulation of an Anode Stalk Support Insulator

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May 18, 2005

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DESIGN AND SIMULATION OF AN ANODE STALK SUPPORT INSULATOR*

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Abstract

An anode stalk support insulator in a magnetically insulated transmission line was designed and modeled. One of the important design criteria is that within space constraints, the electric field along the insulator surface has to be minimized in order to prevent a surface flashover. In order to further reduce the field on the insulator surface, metal rings between insulator layers were also specially shaped. To facilitate the design process, electric field simulations were performed to determine the maximum field stress on the insulator surfaces and the transmission line chamber.

INTRODUCTION

A pulsed X-ray source for radiography was developed at Lawrence Livermore National Laboratory [1]. The goal of this project is a flashed, isotropic, point X-ray source. A commercial power supply was used to produce a 1.5-MV, 20-KA, 20ns pulse. Power is channeled through a magnetically insulated transmission line (MITL) to a diode. Thin solenoid is contained is the outer wall of the MITL. A new configuration (Figure 1) has been proposed for blast protection. In the figure, the original configuration which includes the Blumlein, insulator stalk, and MITL is shown on the left. In the new proposed configuration, an anode stalk and its support insulator (on the right) have been added and are perpendicular to the original configuration. The anode stalk support insulator needs to hold up to 1.5 MV.
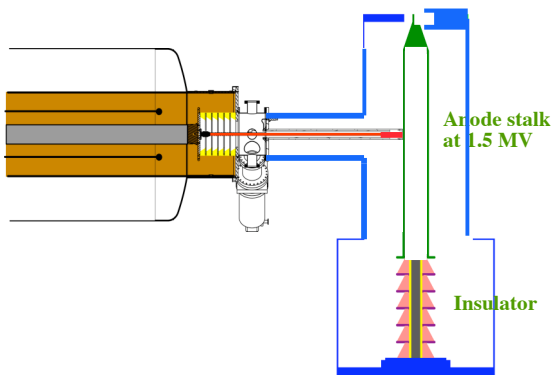

Figure 1: Overall Configuration.

INSULATOR DESIGN

Figure 2 shows the design of the anode stalk and its support insulator. One important design consideration is to minimize the electric field along the insulator surface within the space allowed in order to prevent the surface flashover. Two chambers of different sizes are used. A chamber with a larger diameter is used on the bottom to reduce the field on the insulator surface. The anode stalk is at 1.5 MV and the insulator base is at ground. There are six insulator layers. The insulator layer is made of Rexolite with dielectric constant equal to 2.53, and is separated by metal grading rings.
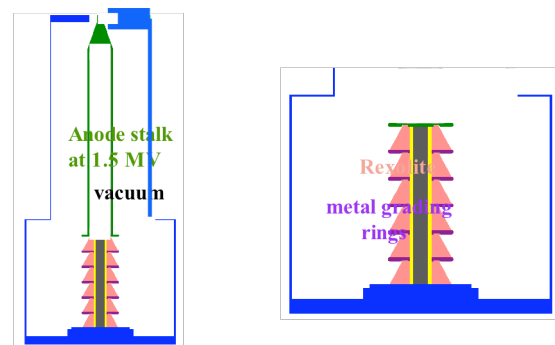

Figure 2: Anode stalk and its support insulator.

A more detailed view of the insulator layer is shown in Figure 3. In the middle of is an insulating rod with dielectric constant equal to 2.8. The rod is surrounded by resistive fluid with dielectric constant equal to 80 and conductivity equal to 0.105 siemans/m. A section is removed in the metal grading ring where top of Rexcolite meets the ring. Metal rings are specially shaped in order to further reduce the field on the insulator surface.

ELECTRIC FIELD SIMULATION

The electric field simulations were performed Tofacilitate the design process and to determine the maximum field stress on the insulator surfaces and the transmission line chamber. Figure 4 shows the voltage plot. The plot shows that the voltage at the anode is at 1.5 MV and reduces to zero at the chamber wall. The voltage drops about 0.3 MV for each layer. The magnitude of the electric field in the insulator region is displayed in Figure 5. The plot shows that high field (> 200 KV/cm) occurs around the edges of the top metal grading ring. Since it takes higher
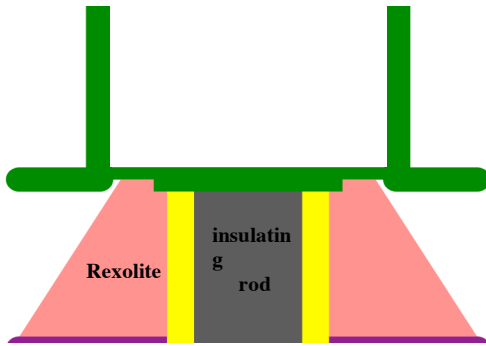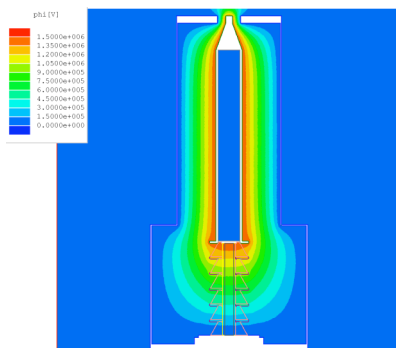
Figure 3: Top layer of the insulator.

Figure 6: E along the top insulator surface.

Figure 4: Voltage plot.
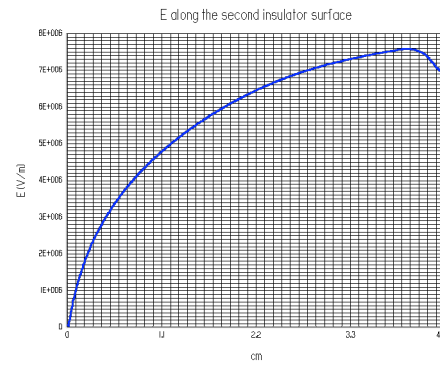
Figure 7: E along the second insulator surface.

field to pull the ions out, we are not concerned about the field here. Since the major concern is the surface flashover, electric fields along the insulator surfaces are plotted in Figures 6 and 7. The results show that the electric fields along the insulator surface are below 90 KV/cm which are smaller than the field which will result in surface flashover.

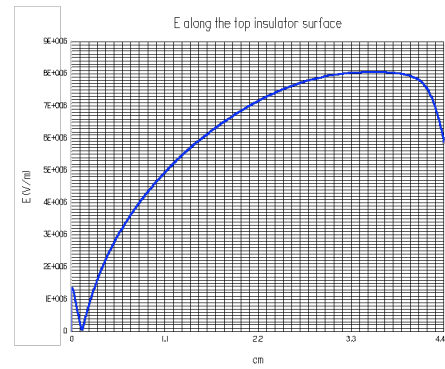In addition to the insulator, the junction of two MITL chambers needs to be shaped. The sharp corners of the junction are rounded with larger wall thickness. The new configuration is shown in Figure 8. Figure 9 displays the plot of magnitude of electric field in the region.
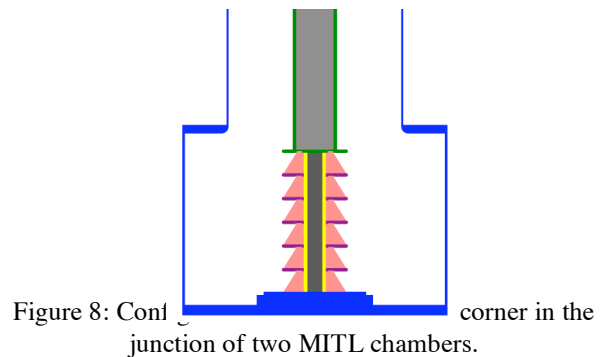

Figure 5: Magnitude of electric field.

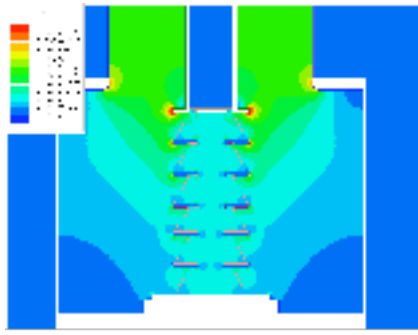Figure 8: Configuration corner in the junction of two MITL chambers.

Figure 9: Configuration with the rounded corner in the junction of two MITL chambers.

Figures 10 and 11 show the electric field around the junction of two chambers with and without the rounded corners. The maximum electric field with rounded corner is reduced to one third of the electric field without rounded corner.
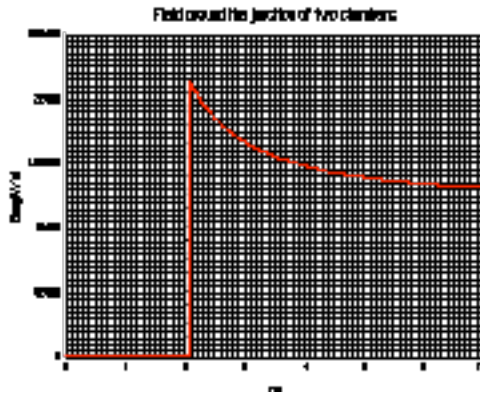

Figure 10: Electric field around the junction of two chambers.

An insulator was fabricated based on this design. The experimental results show that there is no arcing nor sparking when the full voltage is applied. The insulator base is sufficiently rigid that the diode can be aligned without additional support. The fabricated insulator is shown in Figure 12. Figure 13 displays the anode stalk and the insulator inside the chamber.

SUMMARY

The anode stalk/support insulator was designed and analyzed using electrostatic simulation. Electric field along the insulator surface is reduced to less than 100 KV/cm with the current design, By rounding the corners of two MITL chambers, electric field was reduced by more than a half in the junction area. The experimental results show there is no surface flashover along the insulator surface when the full voltage is applied.
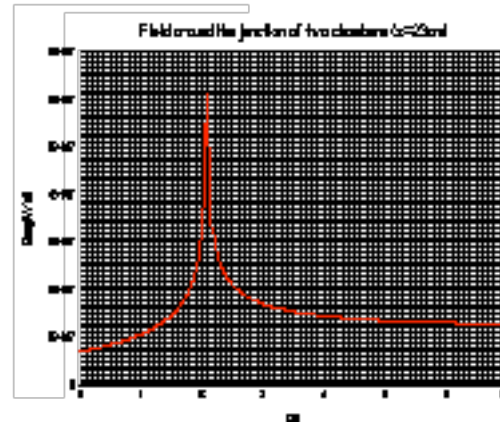
Figure 11: Electric field around the junction of two chambers without the rounded corners.

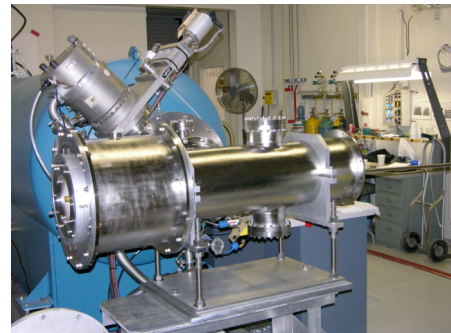Figure 12: An insulator based on this design was fabricated.

Figure 13: Insulator (inside the chamber) and the anode stalk.

REFERENCES

[1] S. Humphries, T. Orzechowski, and J. McCarrick, "Simulation Tools for High-Intensity Radiographic Diodes," PAC'03, Portland, Oregon, May 2003, p. 3557,